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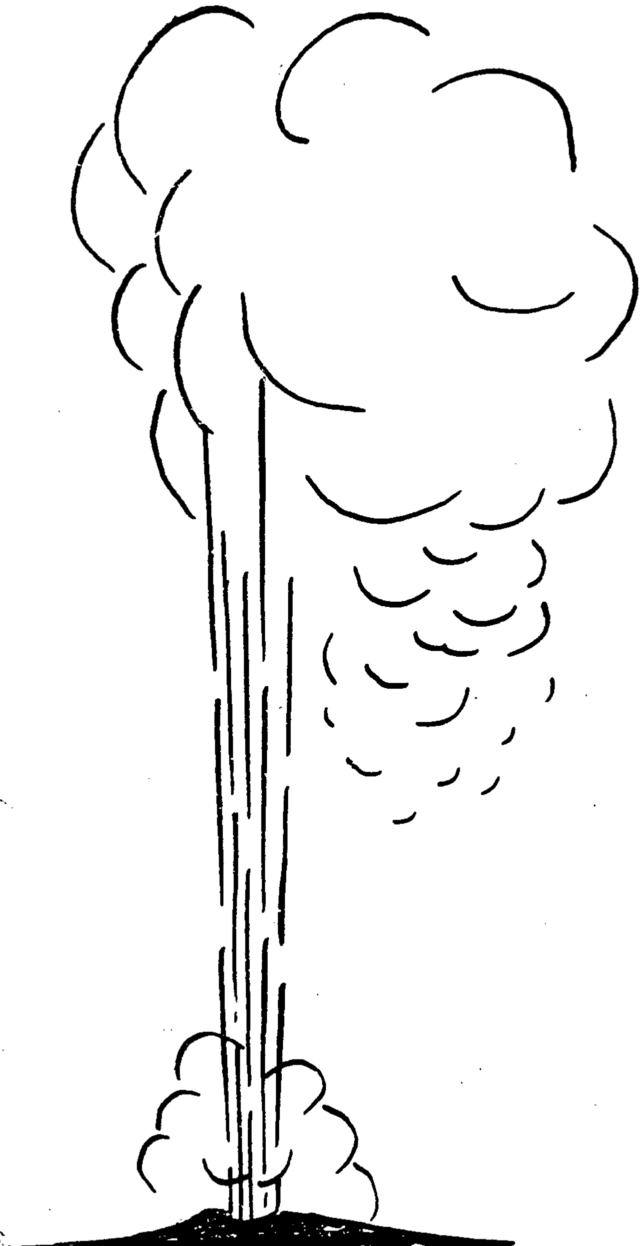

RESEARCH AND DEVELOPMENT OF INFORMATION ON GEOTHERMAL DIRECT HEAT APPLICATION PROJECTS

FIRST ANNUAL REPORT
OCTOBER 1980 TO SEPTEMBER 1981

William F. Hederman, Jr.
Laura A. Cohen

October 1981

Work Performed Under
Contract/Number DE-AC07-80ID12099
for the
Idaho Operations Office

ICF Incorporated
Washington, D.C.

U. S. DEPARTMENT OF ENERGY

Geothermal Energy

DISCLAIMER

DOE/ID/12099-A1

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I. INTRODUCTION

This is the first annual report of ICF's geothermal R&D project for the Department of Energy's Idaho Operations Office. The overall objective of this project is to compile, analyze, and report on data from geothermal direct heat application projects. Ultimately, this research should convey the information developed through DOE's and Program Opportunity Notice (PON) activities as well as through other pioneering geothermal direct heat application projects to audiences which can use the early results in new, independent initiatives. A key audience is potential geothermal investors.

GENERAL APPROACH

The general approach employed in this project emphasizes gearing the data collection and analysis efforts to specific purposes for which the data and analytic results would be used. This analytical focus was selected to avoid the situation where the needed data would not be available and the available data would not be needed.

The original plan included four project tasks:

- compilation of a data base
- data evaluation and analysis
- identification of barriers
- reporting.

Project accomplishments in each of these four task areas are summarized next. This brief summary is followed by an outline of the remainder of this annual report.

MAJOR ACCOMPLISHMENTS

The original project plan called for major emphasis in the project's first year on data collection and data base development, but this plan was modified very shortly after the project began. In the Fall of 1980, DOE's geothermal energy division learned that major budgetary reductions for demonstration activity such as the PON projects appeared quite likely. This suggested that the research and development of information efforts should become more narrowly focused rather than be geared towards developing a very large data base that would have little chance of being maintained in the longer run.

This first year's efforts, then, led to the following accomplishments:

Compilation of a data base: The ICF data gathering efforts emphasized two major goals, the development of a comprehensive data collection device, and the collection of detailed cost and performance data from advanced geothermal direct heat projects.

A comprehensive, 33-page data collection form for all geothermal direct heat application projects has been drafted, reviewed by selected project personnel, EG&G staff, and DOE, and revised. The revised form is included as Appendix A to this report. This data collection form has provided the basis for the development by EG&G of a standardized final report format for all PON projects. The final report format will allow the collection of application project data in a complete, comparable manner that should permit quick review by parties interested in any aspect of geothermal direct heat applications across PON projects.

Secondly, we collected from five advanced PON projects the data necessary to perform a comparative economic analysis (described below). This effort included the identification of proper tax treatment for twenty investment cost categories.

Data evaluation and analysis: The evaluation and analysis efforts have emphasized the comparative economic analysis. The approach involved: 1) using collected project cost and performance data to estimate energy supply costs for geothermal direct heat, and 2) developing a standardized economic framework for comparison with alternative energy supplies. Projections of conventional fossil fuel prices have also been used to compare geothermal and conventional energy supply costs. Results of the analysis show that at each of the projectes reviewed, geothermal direct heat energy is estimated to cost less than conventional energy supplies.

Identification of barriers: This particular analytic issue has been examined within the context of the comparative economic analysis. The potentially critical barrier of a major cost disadvantage does not appear to exist for the projects reviewed. Moreover, the groundwork has been laid through the preliminary economic analysis to assess the potential effects of changes in tax regulations (such as minimum temperature requirements, energy tax credit changes, or treatment of hybrid systems) and environmental quality control measures (such as reinjection of geothermal fluids).

Reporting: The findings of the preliminary economic analysis have been reported in several ways. The analysis and its results are presented in an interim topical report, Economic Assessment of Geothermal Direct Heat Technology: A Review of Five DOE Demonstration Projects, DOE/ID/12099-1, June 1981. The results have also been reported in an April briefing to DOE Geothermal Energy Program staff, to the DOE Geothermal Direct Heat Applications Program Semi-Annual Meeting (September 1981) and in a meeting of the Rocky Mountain Basin and Range State Geothermal Commercialization Teams (September

1981). Similar presentations are planned for the Geothermal Resources Council annual meeting (October 1981) and the International Association of Energy Economists annual meeting (November 1981).

OVERVIEW OF THE REPORT

The next section of this report presents a brief chronological summary of the project's first year, followed by a summary of results to date. The results are outlined by the reporting requirements of this project, under each of the nine report topics:

- resource assessment
- well drilling and resource development
- system design, construction, and operation
- space and district heating systems
- industrial processing systems
- agricultural systems
- economics
- environmental and institutional considerations
- potential for future development

The final chapter addresses potentially useful steps for future work.

II. CHRONOLOGICAL REVIEW

One of the most useful means of establishing the progress of a research effort is to review the results and how they were obtained. The results, or accomplishments, of the project's first year were highlighted in the Introduction and are discussed in greater detail in the third chapter of this report. This chapter describes the context in which these results were developed by providing a brief chronological narrative of the project's progress. These first year activities are summarized by quarter.

PROJECT START-UP (FIRST QUARTER)

The first quarter of the project (October to December 1980) dealt with commencing the project. This included action in all four project tasks.

Early efforts in the area of data base compilation sought to determine what the important data elements were and to design a vehicle for gathering that data. A major literature review of material discussing geothermal energy development, commercialization, and related issues formed an important part of these early activities. In addition, data were reviewed from several projects for which reports were readily available from the project officer (F.W. Childs of EG&G Idaho). The project materials reviewed included:

- Contract Documents
- Interim Progress Reports
- Environmental Reports
- Drilling Specifications
- Corrosion Test Reports, and
- System Design Plans

Using insights developed from the literature and report reviews, ICF drafted a geothermal direct heat application data collection form. The draft form was distributed at the November 1980 Geothermal Direct Heat Program semi-annual meeting in Las Vegas to DOE and EG&G personnel and to several PON project directors whose projects were nearing completion. From discussions stimulated by review of this draft form arose the possibility of using this form as a major part of project final reports. Additional first quarter efforts included amassing specific cost and performance data for advanced PON projects as one part of the preliminary economic analysis issue (discussed below).

Evaluation and analysis efforts included a review of the project work plan with the technical monitor, and the identification of major analytic items for the preliminary economic analysis. The preliminary economic analysis was identified at the Las Vegas program meeting as a major aspect of the first year's effort. This shift away from a data collection emphasis arose from the anticipated federal budget reductions in the area of geothermal direct heat applications. The consensus that developed among DOE, EG&G, and ICF staff was that if a large, computerized data base were unlikely to be maintained in the long run, then there was little sense in developing it. Instead, it was felt that the successful performance of several advanced PON projects would allow important overview analyses to proceed. Therefore, data base development efforts were postponed pending a better sense of likely future outcomes.

Barrier identification efforts during the first quarter began with parts of the geothermal literature review. Other aspects included the specification of data concerning potential technological, economic, institutional, or legal barriers which would be included in the data collection effort. Special attention was devoted to major tax policy issues relevant to investments in goethermal energy.

Reporting activity was fairly limited in this initial stage of the project. However, ICF prepared and distributed the draft data collection form, presented a report and briefing to the November semi-annual meeting, and reported to DOE and EG&G on energy supply cost standardization issues.

ECONOMIC DATA GATHERING/EARLY ANALYSIS (SECOND QUARTER)

During the second quarter of the year, the preliminary economic analysis of geothermal direct heat applications was the primary focus of the project. Activity during this period covered all four task areas.

A "pilot" effort was made to collect all cost data for one application project in order to determine the detail required for an accurate financial analysis and to assess the feasibility of gathering all required data from existing project documentation. Existing documentation, especially monthly voucher summaries from EG&G, proved helpful as an initial source, but required supplementary conversations with project staff to determine the allocation of costs in greater detail. Efforts were also made to collect data from other projects and to overcome the problems encountered in these collection efforts. The process involved collection of data for three additional advanced PON projects.

At the same time, steps were taken to collect data on applicable federal and state tax provisions and on alternative fuel prices. In addition, when it became clear that DOE computer facilities would not be available for any data base development, ICF gathered data on the costs of implementing such a data base management system on private computer facilities.

Significant evaluation and analysis efforts began during this period. The projections of alternative fuel costs were developed. Financial parameter inputs (e.g., return on equity, inflation, tax rates) were established, and tax treatment issues were analyzed. The first comparative analyses of geothermal direct heat energy and alternative energy supplies were completed, and the results indicated that geothermal could be quite economical.

With respect to potential barriers to geothermal direct heat technology, ICF began to probe the cost of environmental regulations to the extent feasible with available projected cost data. In addition, we examined the implications of federal tax policy on project economics. At the suggestion of the technical monitor, ICF staff also participated in a National Bureau of Standards district heating round table exercise.

During this period, reporting activity centered on two efforts: an initial draft report on the economic comparison and a briefing to DOE staff on this analysis.

ANALYSIS OF PROJECT ECONOMICS (THIRD QUARTER)

During the third quarter, the complete preliminary economic analysis was presented, critiqued, revised, and published.

Data compilation continued during this period. ICF finalized cost and production data for the five advanced PON projects included in the preliminary economic analysis. Raw data from additional application projects were also gathered and reviewed during this time. Efforts were made to obtain complete sets of data from more projects for inclusion in the preliminary economic analysis, but these efforts proved unsuccessful.

The evaluation and analysis task formed the major part of this period's activity. The final analysis was completed for the cost and performance data from the five PON projects reviewed. The final projections of the relevant alternative fuel costs were also completed. These two efforts were then combined to prepare the comparative economic assessment of geothermal versus conventional energy supplies.

The identification of barriers proceeded and ICF found that one potentially critical barrier, a major cost disadvantage for geothermal supplies, did not exist for the projects reviewed, given current cost and production estimates. Other specific barrier issues that received special attention included the explicit analysis of the effects of selected tax treatments, and an exploration of the cost effects for geothermal supplies of stringent environmental controls such as re-injection requirements.

Reporting during this period consisted of a briefing to DOE staff, the transmittal of the draft interim topical report, the discussion of the draft with DOE and EG&G staff, and the transmittal of the revised interim topical report. The full interim topical report reference follows:

ICF Incorporated, Economic Assessment of Geothermal Direct Heat Technology: A Review of Five DOE Demonstration Projects, Interim Topical Report, October 1980 to 1981, DOE/ID/12099-1, June 1981, work performed under contract number DE-AC07-80ID12099 for the Idaho Operations Office, Geothermal Energy Program, U.S. Department of Energy.

DISSEMINATION OF PRELIMINARY RESULTS (FOURTH QUARTER)

The activity during the final quarter of the first year emphasized communicating the results of the preliminary economic analysis. These dissemination activities included:

- Preparation and submission of a paper for the Geothermal Resources Council 1981 Annual Meeting in Houston, Texas, October 1981. (Paper accepted for the Economics and Financial session.)

- Preparation and presentation of a paper to a meeting of the DOE sponsored Rocky Mountain Basin and Range State Geothermal Commercialization Teams at Custer, South Dakota (September 1981).

- Preparation and presentation of a paper to the semi-annual meeting of the DOE Geothermal Direct Heat Program Opportunity Notice Project Teams at Boise, Idaho (September 1981).

- Preparation and submission of a paper for the annual North American meeting of the International Association of Energy Economists in Houston, Texas, November 1981. (Paper accepted for New Energy Technologies session.)

III. RESULTS TO DATE

This chapter reviews the results of the project's first year. Because of the re-direction of the project shortly after its commencement, the greatest progress by far has been achieved in understanding the economics of geothermal direct heat applications. The project contract stipulates, however, that the annual report specifically address each of the topical report issues, and the project monitor has requested that the discussion be organized accordingly.

These nine topics can be grouped into three broad classes. The first three topics address technical issues associated with resource exploitation: resource assessment, well drilling and resource development; and system design, construction, and operation. The second three topics address specific types of geothermal direct heat applications: space and district heating systems, industrial processing systems, and agricultural systems. The final three topics provide focused overviews of the geothermal direct heat application project experiences. They address economics, environmental and institutional considerations, and potential for future development.

Findings associated with each of these topics are discussed below.

RESOURCE ASSESSMENT

Geothermal resources which serve as energy sources for geothermal direct heat applications can be of much lower quality than the resources required for geothermal electricity generation, the major form of geothermal energy use at present. Such low to moderate temperature resources appear to have potential occurrence throughout most of the western continental United States, as well as some parts of the South, Great Lakes region, and Middle-Atlantic states.

Because these resources are more widespread than the higher temperature resources, they have not been as carefully reviewed at this time. Figure III-1, however, provides an overview of the latest assessment of the extent of geothermal resources underlying the United States.

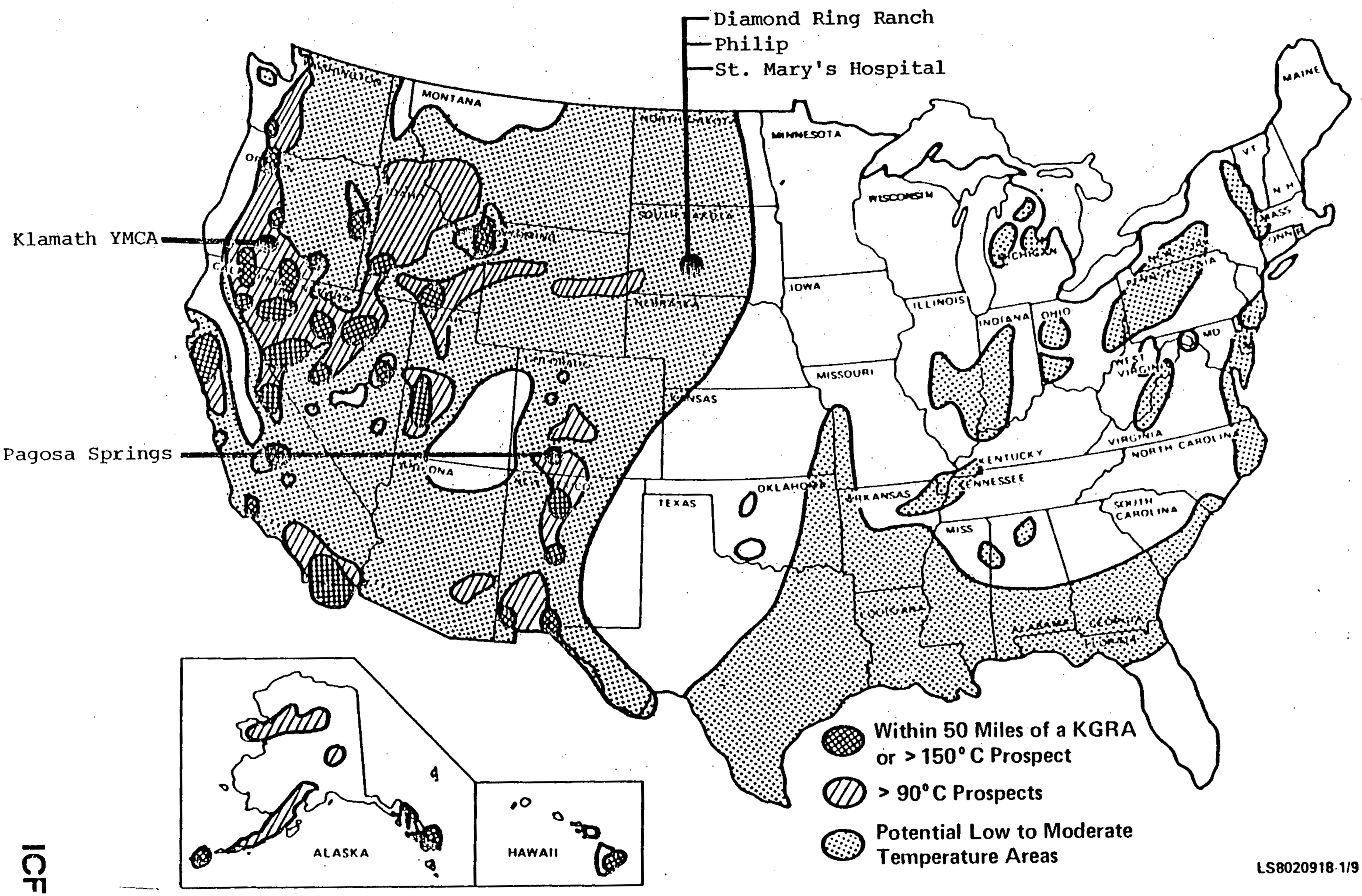
As mentioned earlier, ICF has undertaken detailed examinations of five advanced projects, emphasizing in particular economic factors. This review provided some insights about the resources with which successful projects are likely to proceed. The resource conditions for these projects were not, in general, unusually favorable, and they varied significantly in temperature, depth, and level of impurities. This range of resources is presented in Table III-1.

There was little perceived uncertainty about the resources used at any of the five advanced projects. The three South Dakota projects all tapped the large, geothermally heated and well-defined Madison Acquifer. The only important surprise concerning this resource was that the temperature at the St. Mary's Hospital project proved to be 11°F (106°F versus 117°F) lower than had been estimated.

Of course, the resources were perceived to be relatively well-understood at all the projects for which any information has been reviewed so far. The major problem of differences between anticipated and actual resource characteristics related to the flow rate of the geothermal fluids. For instance, geothermal fluid flow rates have proven inadequate at Warm Springs State Hospital in Deer Lodge County, Montana (a space and domestic water heating application).

FIGURE I-1

KNOWN AND POTENTIAL HYDROTHERMAL RESOURCES



SOURCE: Interagency Geothermal Coordinating Council, Geothermal Energy, Research, Development and Demonstration Program: Fourth Annual Report (DOE/RA-0050; IGCC-5) Washington, D.C., June 1980, p. 20.

TABLE III-1

RESOURCES OF THE FIVE ADVANCED
PON PROJECTS REVIEWED

Project	Well Depth (feet)	Temperature (°F)	Flow Rate (gallons per minute)
Diamond Ring Ranch	4,100	152	170
St. Mary's Hospital	2,200	106	375
Klamath YMCA	1,400	147	310
Pagosa Springs, CO	275	148	1,200
	300	131	600
Philip, S.D.	4,300	157	300

Another type of potential problem uncovered in ICF's research is that a resource assessment may not adequately identify the quality of geothermal fluids. The Philip, South Dakota project provides a good example of these risks. This project provides space and domestic water heating for a school and a limited district heating system. The U.S. Environmental Protection Agency tested Philip geothermal fluids and discovered Radium 226 at levels in excess of federal standards for drinking water (99 pico curies per liter versus a 5 pico curies per liter maximum acceptable level). The Philip project was therefore forced to incur the unanticipated expense of adding a Barium Chloride Treatment facility to remove 99 percent of the Radium 226. Only then could the fluids be discharged into the Bad River.

Data concerning the accuracy of a resource's estimated useful lifespan remain to be developed. Since the projects had operated for a maximum of less than two years when reviewed, significant information could not be gathered on reservoir lifespans.

Other potential resource-related problems are more closely associated with well drilling and resource development, both of which are discussed in the next section.

This project's data collection plans include reporting of the following data elements for each resource assessment exercise identified:

- Assessment type (estimate or actual measurement)
- Assessment date
- Type of geothermal resource (water dominated, vapor dominated, geo-pressured, hot dry rock)
- Temperature range
- Temperature (best estimate or actual)
- Temperature gradient
- Flow rate
- Drilling depth

- Reservoir life span
- Reservoir pressure
- Wellhead pressure
- Fluid quality
    - TDS
    - Salinity
    - Other
- Unique resource characteristics
- Assessment performer
- Time to complete assessment
- Assessment cost
- Assessment technique
- Problems encountered

WELL DRILLING AND RESOURCE DEVELOPMENT

The well drilling and resource development phases comprise key steps in the success of a geothermal direct heat application project. All five projects reviewed in the economic analysis were successful in completing production wells and, where necessary, re-injection wells.

Only four of the five projects, however, drilled wells; the Diamond Ring Ranch used an existing well. There have been some problems with the wells at these projects. For instance, the Pagosa Springs, Colorado district heating project had also planned on using existing wells, but problems concerning the integrity of the existing wells arose and the project team decided to drill new wells. Three wells were drilled to obtain two production wells; the other hole was cemented closed. Another problem arose when the production well at the Klamath YMCA required proper cleaning through air surge and extended, continuous pump testing.

Other specific issues have also been identified as potentially significant for geothermal projects. These include the contract letting processing for the driller (e.g., the importance of a competitive bid process), and the use of water-well drillers (as opposed to oil-well drillers) and the communication to such drillers that they could perform the tasks necessary for geothermal well development.

The current data collection plan calls for gathering the following data elements for each well at a project:

- Date of estimate or measurement
- Well depth
- Bottomhole temperature
- Wellhead temperature
- Temperature gradient
- Flow rates
    - Daily peak
    - Annual average
    - Summer average
    - Winter average
    - Production peak season average
- Bottomhole static pressure
- Drilling technique
- Casing material
- Percent of well depth hard rock
- Downhole/re-injection pumps
    - Number
    - Size
- Expected useful life of well
- Drilling start date
- Drilling costs
- Other costs
- Well O&M expenses
- Well completion method
- Drilling firm type and experience
- Special features
- Problems encountered and how they were overcome.

The plan calls for these data to be collected for every well (successful or not) and for each estimate or actual measurement at each well.

SYSTEM DESIGN, CONSTRUCTION, AND OPERATION

The geothermal direct heat system design, construction, and operation activities vary to a greater degree with a project's particular application than do the previous elements. The key elements of the direct heat utilization system include the transmission pipelines from the wells to the application site, the heat extraction equipment, the distribution system, the heating equipment, and the disposal system. The construction information relates directly to the parts of the heat utilization system just mentioned, while the operations data relate both to the components mentioned above and to more general aspects of project operations.

The data elements planned for collection concerning transmission pipelines include the following:

- Transmission line length
- Pipe diameter
- Kind and thickness of insulation
- Inlet temperature and pressure
- Outlet temperature and pressure
- Heat loss in pipeline
- Flow rate
- Number and size of pumps
- Piping material
- Special features of transmission system
- Map of system

Transmission system construction data will include:

- Start and completion dates
- Expected useful life
- Capital costs
  - Total
  - Per unit, if applicable
- Firm involved (and types)
- Contractual arrangements
- Problems encountered and how overcome.

These data should be presented for each transmission loop and information about original estimates and designs as well as actual costs, schedules, etc. should be reported.

For heat extraction and distribution data reporting would include the following:

- Number of heat exchangers
- Heat exchanger type
- Location of heat exchanger(s) (well site or application site)
- Inlet/outlet temperatures of geothermal fluid
- Inlet/outlet temperatures of secondary fluid
- Metering equipment
- Any cascading from one use to another
- Heat transfer performance of exchangers
- Expected useful life of equipment.

Construction data would include:

- Start-up and completion dates
- Capital costs
- Installation costs
- Identity and types of firms
- Contractual arrangements.

Again, these data would be collected for estimated and actual figures.

The distribution system data would be analogous to those for the transmission subsystem. The data for heating equipment at point of use would be similar in nature to the heat exchanger data, but would include retrofit data when appropriate.

The extent of disposal data would vary according to the environmental restraints imposed. Included would be:

- Disposal system type (e.g., deep-well reinjection or direct discharge into surface waters)
- Treatment required
- Capital costs
- Environmental restrictions encountered
  - Type
  - Source
  - Resolution of problem
- Other problems encountered and how overcome.

Again, estimated and actual figures whould be reported.

The operations data for projects would also vary considerably by application. In general, however, the data would include the following items:

- Organization structure and responsibility for operations
- Federal involvement in operations
- Load-factor (estimated/actual)
- Description of down-time
- Other operational data
  - Flow rate
  - Temperatures
  - Loads
- O&M costs by system components (estimated/actual)
- Problems encountered and how overcome
- Billing system description

SPACE AND DISTRICT HEATING SYSTEMS

Space, water, and district heating systems represent some of the most common applications of geothermal direct heat energy. Geothermal district heating systems have existed in Boise since 1890; new systems are being operated and built in a number of cities, including Pagosa Springs, Philip, Klamath Falls, Susanville, and El Centro. The technology of geothermal space and water heating is well understood. Existing radiators and heating coils can easily be adapted for use with geothermal energy. In some cases geothermal fluid can be used directly in heating systems, replacing or supplementing boiler fluid. Alternatively, if the danger of corrosion is high, heat exchangers can be employed to transfer heat from the geothermal fluid to clean water which is then circulated through the heating system. Geothermal direct heat energy can be economically employed in smaller space heating projects for single structures (as, for example, at the St. Mary's hospital or the Klamath Falls YMCA) or for larger district heating systems which distribute geothermally heated fluid through a number of buildings. Space and water heating systems can utilize a wide range of geothermal temperatures; if geothermal fluid temperatures are not high enough to completely supply energy needs, they can still be used for preheating, thus reducing boiler fuel expenses.

Our initial economic study focused on determining the costs of supplying geothermal and conventional energy to five PON projects, all of which involved space heating applications. The Diamond Ring Ranch project, which uses geothermal energy for both space heating and grain drying, is discussed in the agricultural applications section of this report; the other four projects are briefly described below.

St. Mary's Hospital

The geothermal heating system at St. Mary's hospital in Pierre, South Dakota has been operational since October 1980. 106°F water from the Madison Aquifer is used for space heating and preheating of domestic hot water in an existing, retrofitted hospital building and in a new hospital wing. The 2200 foot well flows at 375 gpm. After flowing through plate-type heat exchangers, the geothermal fluid is discharged into the Missouri River. The geothermal system will deliver up to 11,440 million Btu per year (supplying 55 percent of hospital heating needs), allowing a yearly savings of approximately 115,000 gallons of fuel oil. Capital costs for the St. Mary's system total $769,000; project staff estimate that yearly O&M costs over the life of the project will be approximately $10,800.

Klamath YMCA

Operation of the geothermal system at the YMCA in Klamath Falls, Oregon began in April 1980. A plate-type stainless steel heat exchanger transfers heat from the 147°F geothermal fluid to a supply of boiler fluid, which is then circulated to heat a swimming pool and provide space and domestic hot water heating to the YMCA building. Geothermal fluid flows at 60 to 250 gpm (depending on heating needs) from a 1400 foot production well and is re-injected into a 2000-foot injection well. The system provides approximately 7,000 million Btu per year. Total capital costs for the project were $285,000; yearly operating costs are $2,100.

Pagosa Springs

In the town of Pagosa Springs, Colorado, a geothermal district heating system will supply heating to at least 127 businesses, residences, and public buildings. Two shallow wells (300 feet and 275 feet) will provide 131°F and 148°F fluid, respectively, from a Dakota sandstone aquifer at a combined total flow rate of up to 1800 gpm. Clean city water will be heated using two plate heat exchangers; afterward, the geothermal fluid will be discharged into the San Juan River. The heated city water will be circulated to users through two independent closed loops. Construction for the distribution system and building retrofit have begun. At capacity, the system is expected to deliver 56,700 million Btu annually, replacing approximately 82,500 million Btu of natural gas. In the first year of operations, now scheduled for the 1981 - 1982 heating season, the geothermal system will operate at approximately 38 percent capacity. Total project capital costs are estimated at $1,462,000; yearly O&M costs will be approximately $50,400 at full capacity.

Philip

The Philip, South Dakota geothermal project comprises a small-scale district heating system. 157°F fluid flowing at 300 gpm from a 4300 foot well in the Madison Aquifer is supplied to five school buildings and then cascaded to eight business district buildings. After treatment in a barium chloride plant to remove Radium 226, the fluid is discharged into the Bad River. The geothermal system displaces 17,800 million Btu currently supplied by fuel oil, propane, and electricity. Operation of the system began in November 1980. The total project capital costs were $1,188,000; yearly O&M costs will total approximately $4,000.

Our analysis of these projects indicates that for these applications, geothermal systems can supply energy needs at costs lower than those of any standard gas, liquid, or solid fossil fuels. Details of this economic analysis are provided later in this report.

In addition, we have received some preliminary cost and/or design data from the PON geothermal district heating system projects in the cities of Boise, Idaho; Susanville, California, Klamath, Oregon; and El Centro, California; from space heating systems planned for a state prison near Salt Lake City, Utah; a condominium complex in Reno, Nevada, three commercial buildings in Elko, Nevada, and a private hospital in Marlin, Texas. These projects range from preliminary design to system construction phases.

Data gathering efforts for space and district heating systems should cover all project phases, including resource assessment, initial design, permitting, financing, well-drilling, system construction, and system operation. In addition, data collection for municipal district heating systems should incorporate creative financing mechanisms, rate-setting designs, metering, and customer billing systems.

INDUSTRIAL PROCESSING SYSTEMS

While much of the geothermal activity to date has focused on space heating applications, industrial process heat represents another important potential use of geothermal energy. Geothermal process heat applications projects initiated thus far have been largely limited to agricultural applications, discussed in the next section, and production of fuel alcohol. As of June 1981, four geothermal ethanol plants were in service, with 53 more under consideration for operation by 1984. If all of these plants are constructed, total geothermal energy consumption for ethanol production by 1984 will be over 16,000 billion Btu annually.

The largest direct heat user of geothermal energy accounting for 10,000 billion Btu per year, or 75 percent of total current geothermal direct heat energy use, is a waterflood oil recovery project in Wyoming. The sheer size of this application suggests it as a target for future investigation. Analyses should focus on the costs and benefits of using geothermal energy in oil recovery applications compared to other potential uses of the geothermal resources, as well as comparison of flooding using geothermally heated rather than unheated water.

Our investigations to date have turned up relatively little data on geothermal industrial applications, since only a few of the PON projects involved industrial process heat. Plans for food processing plants in California and Idaho have been abandoned. The Elko, Nevada PON project includes plans for a geothermal retrofit of a laundry facility to heat water for washing machines. This project was still at a relatively early stage of development at the time of our first year analyses, which focused only on the most advanced projects from which more actual (rather than estimated) data were available.

While geothermal industrial process heat activity to date has been minimal, the potential for utilizing moderate temperature geothermal fluids in process heating applications is quite extensive. Industry accounts for about 40 percent of U.S. energy consumption, and process heat consumes almost 70 percent of industrial energy. 1/ While many of these industrial applications require temperatures substantially greater than those typically available from geothermal energy, 35 percent of all process heat is used in applications that require temperatures below 350 degrees Fahrenheit. 2/ Table II-2 lists some of the industrial and agricultural process heating applications most suitable for geothermal energy, noting the required temperatures for each process. Our future work may include a more extensive investigation of potential industrial users of geothermal energy and an identification of the match between industry locations and heat requirements and available geothermal resources.

AGRICULTURAL SYSTEMS

Geothermal direct heat energy is ideally suited to many agricultural applications. These include greenhouse heating, crop drying, animal husbandry, food processing, and fish farming. Two agricultural PON projects are already operational: Aquafarms International and the Diamond Ring Ranch. The Diamond Ring Ranch geothermal project was one of five advanced projects included in our initial economic assessment of geothermal direct heat energy. In addition to space heating, the Diamond Ring Ranch used geothermal

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1/ Malcolm D. Fraser, "Analysis of the Economic Potential of Solar Thermal Energy to Provide Industrial Process Heat in the United States," Proceedings of the 1978 Annual Meeting, American Section of the International Solar Energy Society, Volume 2-1, August 28-31, 1978, p. 947.

2/ Battelle Columbus Laboratories, "Survey of the Application of Solar Thermal Energy Systems to Industrial Process Heat, Final Report," Volume I, TID-27348-1, January 1977, p. iv.

TABLE III-2

TEMPERATURES REQUIRED FOR SPECIFIC END-USE APPLICATIONS

Temperature	Application
	In-the-can cooking of vegetables
250°F	Soybean oil distillation
	Most multiple effect evaporations
	Rendering of animal fats and oils
	Protein denaturization in soybeans
225	Distillation of pure water
	Blanching clams
	Soybean drying
	Fruit juice pasteurization
	Corn drying
200	Tobacco redrying
	Preheat boiler feed water for steam production
	Hydronic space heating
	Lumber drying (soft woods)
	Soap manufacturing
175	Vegetable blanching
	Lower limit of absorption air-conditioning
	Milk pasteurization
	Clean-up water for food processing plants
	Hardwood lumber drying
150	Bottle washing for soft drinks
	Wet capsule formation in pharmaceuticals
	Hot water for oyster gapping
	Domestic hot water
	Poultry plant scalding water
125	Metal plating solutions
	Caustic peeling of tomatoes
	Forced air space heating
	Aluminum and magnexium hydroxide production
100	Egg incubation
	Bottle warming for soft drinks
	Poultry house space heating for chicks
	Soil warming and greenhouses
	Rinse water for soft drink bottling and canning
	Poultry house space heating for mature chickens
75	Aquaculture
50	

Source: Definition of Markets for Geothermal Energy in the Northern Atlantic Coastal Plan, Johns Hopkins University Applied Physics Laboratory, May 1980, p. 24.

fluid to supply process heat for a 700 bushel per hour grain dryer. The system, which began operations in the fall of 1979, delivers 7,800 million Btu per year, displacing 185,000 kwh of electricity and 49,400 gallons of propane. 152°F fluid from a 4100 foot well drilled into the Madison Aquifer in 1959 flows at approximately 170 gallons per minute. After circulating through the grain dryer or through a plate-type isolation heat exchanger, the geothermal fluid is discharged to surface reservoirs. Project capital costs, including the costs which would have been incurred in drilling a new well, total $489,000; yearly operating and maintenance expenses are expected to be $5,000.

Additional agricultural PON projects for which we have received some preliminary cost and design data include Aquafarms International and Utah Roses. Both of these projects are briefly described below.

- The Utah Roses project will utilize geothermal energy to provide space heating for a greenhouse in Sandy, Utah. 124°F geothermal fluid is expected to supply 25 percent of heating requirements, with an anticipated fuel savings of 14 MMcf of natural gas and 40,000 gallons of fuel oil.
- At Aquafarms International, 79°F. water from several geothermal wells is pumped directly to ponds which are used for year-round prawn farming. Total yearly energy use is expected to be 170 billion Btu.

During the first year of this information research and development project, we performed a thorough economic analysis of one agricultural geothermal project: the Diamond Ring Ranch. Our analysis indicated that the cost of geothermal energy to a private developer under circumstances similar to those at the Diamond Ring Ranch would be approximately $4.65 per MMBtu of conventional energy displaced. This compares to levelized prices for comparable amounts of conventional fuels ranging from $5.65 per MMBtu for natural gas to $8.65 per MMBtu for distillate oil. Details of our economic analysis are provided below.

ECONOMICS

The major portion of our efforts during the first year of this project focused on an economic comparison of direct heating applications with conventional heating fuels. All the projects analyzed involved replacing conventional fluids (e.g., natural gas and fuel oils) with geothermal energy in existing heating systems. The cost of using geothermal energy in existing systems was also compared with the cost of new coal-fired equipment.

The costs for the geothermal retrofit projects were estimated from the results to date in five projects which were partially funded by the U.S. Department of Energy (DOE). These cost estimates are highly realistic since four of the five projects are operational and the other project is currently under construction. The five projects examined are the Diamond Ring Ranch space heating and grain-drying operation, the Kamath YMCA and St. Mary's Hospital space and water heating systems, and the Pagosa Springs and Philip district heating systems.

The approach used to compare the projects was a discounted cash flow analysis. The costs of the different projects were adjusted to account for the particular financial situation faced by each of three types of investors:

- private, for-profit firms
- non-profit organizations without tax exempt bond authority, and
- local governments (or non-profit organizations with tax-exempt bond authority).

The costs of all fuel alternatives for each investor type were then converted to a levelized unit cost (in constant dollars) of conventional energy displaced over the projected life of the geothermal project. Conventional fuel prices were estimated based on a recent DOE world oil price forecast in which oil prices increase about three percent annually.

Subsequently, a sensitivity analysis was performed to assess the effect of changes in the original assumptions. The assumptions which were altered in the sensitivity analysis included project costs, geothermal fluid flow over time, financing, federal tax policy, and world oil prices.

Table III-3 summarizes the results of the Base Case economic comparison. The table shows that for each of the potential investor categories examined, the full range of geothermal energy costs lies below the range of the conventional fuel costs. The sensitivity analysis indicated that geothermal energy maintains its economic advantage under most circumstances.

TABLE III-3

COMPARISON OF BASE CASE COST ESTIMATE RANGES
(1980 dollars per million Btu)

Investor Type	Range of Cost Estimates: Geothermal	Range of Cost Estimates: Conventional Fuels
Profit, for-profit	\$2.37 - \$5.73	\$5.82 - \$ 9.33
Non-profit[1]	\$1.77 - \$4.17	\$6.10 - \$10.34
Local government[2]	\$1.33 - \$2.65	\$6.28 - \$10.79

[1] Without tax-exempt bond authority.
[2] Or non-profit with tax-exempt bond authority.

The difference between the geothermal costs and conventional fuel costs (except for new coal projects) are least for the private, for-profit investor and greatest for the local government investor. The major cause of the differences between investor groups is that the private, for-profit firm must pay taxes and faces a higher cost of capital and relevant discount rate than government and non-profit institutions.

Within each investor category, the costs for different geothermal projects vary significantly. Five projects are not sufficient to assess conclusively the relative importance of different application or resource characteristics in the determination of unit costs, but it appears that well depth is a particularly important determinant of geothermal energy supply costs. Other factors that may prove important include geothermal fluid temperature, flow rate, and well capacity utilization.

Our economic assessment indicates that geothermal energy can provide an economical alternative to conventional fossil fuels in low temperature heating applications. The cost estimates developed should be applicable to similar projects where the geothermal resource resembles the resources used in the projects examined. Consequently, potential investors in geothermal direct heat applications can use the results of this study to evaluate the economic attractiveness of proposed projects in some specific locations.

ENVIRONMENTAL AND INSTITUTIONAL CONSIDERATIONS

Although geothermal direct heat applications have proven their economic viability through decades of successful operation at scores of sites, development has remained at a rather low level. There are many reasons for such low levels of development. These reasons include uncertainty about resources and uncertainty concerning relatively large-scale applications of geothermal direct heat, of which there have been few. Potential environmental constraints and other institutional factors, however, also appear to play a major role in the hesitancy of potential geothermal direct heat investors.

Certainly, the length of time required for planning a project, obtaining all the necessary permits, completing exploration (at unexplored sites), and constructing a system constitute important considerations for potential investors. Environmental regulations can play a key role in determining the time requirements for initiating a geothermal direct heat project, and the data collection plan that will be implemented with the standardized final report format is designed to develop insights into how these factors might delay projects.

Data related to environmental considerations that will be gathered include:

- Environmental Report
  - Preparer
  - Start/completion dates
  - Cost
  - Reviewers
  - Review completion date
  - Changes required (in project, in report)
- Permits required
  - Regulator (federal, state, local)
  - Title
  - Date request submitted
  - Data approved
  - Unusual problems
- Effects of legislation on project approval process, including
  - National Environmental Policy Act
  - Clear Air Act
  - Clean Water Act
  - Federal Water Pollution Control Act
  - Solid Waste Disposal Act
  - Safe Drinking Water Act
  - Noise Control Act
  - Marine Protection and Sanctuaries Act

Resource Conservation and Recovery Act
Federal Land Policy and Management Act
Endangered Species Act
National Pollution Discharge Effluent System Act
Arts and Artifacts Indemnity Act
Toxic Substances Control Act
Endangered American Wilderness Act
Non-Game Fish and Wildlife Act
Historic Preservation Act
Occupational Safety and Health Act
Forest and Rangeland Renewable Resources Act
National Forest Management Act

- Effects of state and local laws or ordinances
- Effects of groups on permitting process (including federal, state, and local agencies, the local community, and other interested parties)
- Disposal system descriptions
- Other environmental safeguards.

In the work to date, the importance of environmental and other institutional factors has arisen periodically in both the general data efforts and the economic analysis. With respect to environmental factors, we have explored the effects of major pollution control techniques on project economics, in particular the barium chloride treatment plant at the Philip project and the addition of re-injection wells at all projects. In the instances examined, we discovered that re-injection well requirements could offset the economic advantage of geothermal energy over natural gas at the Philip site, but that the other projects examined could remain less costly than natural gas even if subject to a re-injection requirement.

Although environmental regulations pose a major set of potential obstacles for geothermal direct heat projects, there are other potentially significant institutional considerations that could impinge upon geothermal development. Two major classes of such factors deal with tax treatment of geothermal investments and financial criteria for investments.

The tax code provisions for geothermal energy projects can provide private for-profit developers with significant tax benefits. There are restrictions on eligibility for these benefits, however, and these restrictions are non-trivial. These tax issues received special attention in Appendix C (Federal Income Tax Treatment of Geothermal Costs) of ICF's interim topical report Economic Assessment of Geothermal Direct Heat Technology. Here we briefly summarize the major points.

Four kinds of tax benefits have special importance for geothermal projects: the expensing of intangible drilling costs, percentage depletion allowances, alternative energy tax credits, and new accelerated depreciation provisions. The tax code allows intangible drilling costs such as labor, fuel, repairs and hauling costs for drilling, completing, and testing geothermal production wells, to be deducted from taxable income in the years incurred rather than depreciated over the tax life of the investment. The costs of acquiring geothermal properties and determining their production potential are recovered through geothermal resource depletion allowances, which may exceed the full acquisition costs through percentage depletion allowances in cases where the energy is sold.[1] The fifteen percent energy investment tax credit, currently authorized through 1985, is available for equipment used to produce, distribute, or use geothermal energy. To qualify for the credit, an energy system must utilize geothermal fluids hotter than 50°C (122°F) and must exclude fossil fuel peaking and topping systems. Finally, the Economic Recovery Tax

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[1] See ICF, Economic Assessment, Appendix C for a discussion of the restrictions on percentage depletion allowances.

Act permits accelerated depreciation schedules that should allow geothermal equipment to be depreciated with a five year tax life on a double declining balance schedule. All of these tax provisions provide major reductions in the effective costs of geothermal energy exploitation.

POTENTIAL FOR FUTURE DEVELOPMENT

Low and moderate temperature geothermal resources, capable of being harnessed for direct heat energy applications, underlie vast portions of the North American continent. (Refer to Figure III-1.) Although impractical in many regions and for many applications, exploitation of geothermal energy could potentially allow significant reductions in future consumption of fossil fuels. Extensive development of this alternative energy source will depend on the reduction of perceived geological risks and uncertainties surrounding geothermal resources, on the elimination of institutional barriers, and most importantly, on the comparative costs of constructing geothermal energy systems. Our economic analysis has shown that, at least for some specific applications and resources, retrofit of existing energy sytems for use with geothermal energy is considerably less costly than continuing to purchase conventional gas and liquid fossil fuels. Commercial prospects for geothermal development would thus appear to be quite favorable. Indeed, interest in geothermal direct heat energy continues to grow. The U.S. Department of Energy reports in its Fifth Geothermal Progress Monitor that 197 new geothermal direct heat projects have been proposed, and feasibility studies are known to be underway for an additional 47 projects. Together, these applications could provide as much as 24 trillion Btu per year.[1]

[1] Geothermal Progress Monitor: Report No. 5, U.S. Department of Energy, Assistant Secretary for Conservation and Renewable Energy, Division of Geothermal Energy, June 1981, pp. 11 and 22.

In developing the geothermal direct heat data collection instruments discussed above, we emphasized the gathering of information from projects already operational or under construction, rather than proposed development efforts. Interest in further geothermal development can be gauged, however, by determining the existence and extent of expansion plans for current projects. Data collection from existing projects should therefore include the following items:

- Potential market for the type of energy provided
- Status of expansion plans
- Likely constraints on expansion, and
- Extent of interest expressed by others in similar systems elsewhere.

IV. NEXT STEPS

Efforts on the Research and Development of Information on Geothermal Direct Heat Application Projects have already experienced an important shift in emphasis in response to changes in DOE's Geothermal Energy Program. As described above, these changes involved de-emphasizing planning for an analytical, investor-oriented data base for geothermal direct heat application projects because the likelihood of permanently maintaining such a data base appeared remote. This de-emphasis was offset by the acceleration of an analytic overview of project economics, which became possible through the successful progress of several PON projects. This section details suggestions for potential efforts during the second year of this project.

The generally favorable preliminary findings in this report indicate the need for additional analysis along several avenues of inquiry. For example, the preliminary findings based on projects using known geothermal resources should be verified further. To the extent feasible, we will also expand the scope of the economic assessment to include the costs associated with identifying and confirming the presence of a useful geothermal resource. In addition, some of the innovative financing approaches successfully introduced at several geothermal direct heat projects deserve attention in the next year of this effort.

The major form of supplemental verification will be the inclusion of economic data for additional PON retrofit projects which have advanced to a stage where their cost and production data could be useful in the analysis. Candidate projects are Susanville (California), T-H-S Hospital (Texas), Klamath Falls (Oregon), Elko (Nevada), Utah Roses (Utah), and Aquafarms (California). When possible we will also try to include direct heat application projects implemented independent of the Department of Energy.

The act of identifying and confirming the quality of a geothermal reserve may or may not lead to an exploitable resource base. Future work on the economics of geothermal direct heat applications needs to estimate the costs of exploratory activities and the risks at each stage of a resource proving unacceptable or of institutional factors disrupting a project.

Drilling partnerships and other innovative financial vehicles have long played important roles in oil and gas development. The young geothermal diret heat industry is just learning how to take advantage of the special government incentives offered to encourage domestic resource development. An analysis of the effect of such incentives on project economics could help focus attention on the options available. The analysis could prove especially helpful in light of the major tax changes Congress and state governments are currently implementing.

Other subjects that will be considered by DOE and its contractors, EG&G and ICF, for analysis in the coming year include (i) further analysis of alternative fuel prices, (ii) exploration of industrial heat requirements in relation to areas of geothermal resource availability, (iii) planning guidelines for geothermal projects, (iv) examination of a potentially major special use of geothermal energy, enhanced oil recovery, and (v) development of the topical report series as a set of basic introductions to the major issues associated with geothermal direct heat applications.

The preliminary evidence gathered thus far indicates that geothermal direct heat can be commercially successful. Our future work will seek to provide more information to potential investors about the range of opportunities for economic exploitation of geothermal direct heat energy.

APPENDIX A

DRAFT DATA COLLECTION FORM

GEOTHERMAL DIRECT HEAT APPLICATIONS DEMONSTRATION PROJECTS
DATA SHEETS

DRAFT FORM FOR DISCUSSION PURPOSES

BASIC PROJECT INFORMATION

Project Name: ____________________

Location: ____________________

Application: ____________________

Size of Application: ____________________

Percent of energy needs to be satisfied by geothermal energy: __________

New heating/process system or retrofit existing system? __________

____

____

Planned Energy Utilization:

Btu (annual): ____________________
Btu (peak): ____________________

Amount and kind of conventional fuel displaced: __________

____

Expected Load Factor: ____________________

____

Number of Production Wells: ____________________
Number of Injection Wells: ____________________

Distance from wells to application site: __________

____

Unusual characteristics: ____________________

____

____

____

Project Operator (organization): ____________________

____

Operator Status (public, private, or nonprofit organization): ____________________

Project Manager (name and phone no.): ____________________

____

Other Participants (name and role): ____________________

____

Resource Ownership: ____________________

____

Total Project Cost:

Latest Estimate: ____________________ Date: ____________________
Actual: ____________________

Project Chronology

	Original Estimate	Latest Estimate	Actual
Application to DOE (response to PON)			
DOE Decision Date			
DOE Contract Date			
Resource & Environmental Assessment			
Preliminary Design/Planning			
Well Drilling			
Well Testing			
Final Design			
Distribution & Utilization Systems Construction			
Start-Up of Operations			
End of Federal Support			

Project Status:

Date: ____________________
Stage: ____________________

Next Step: ____________________

On Schedule?: ____________________
Main reason for delays: ____________________

____

Reasons for selection of project: ______________________________

PRE-PROJECT ACTIVITIES

Origin of idea for project: ______________________________

Extent of knowledge of resource prior to project initiation: ____________

Is this a Known Geothermal Resource Area (KGRA)? ______________

Was there a feasibility study?: ______________________

If yes, study dates: Start ______________________
Completion ______________________

Performer: ______________________________

Areas examined and findings:

Geology: ______________________________

Technology: ______________________________

Market: ______________________________

Cost: ______________________________

Other: ____

What sorts of other expert advice were sought prior to project initiation?: ____

If pre-project analyses identified problems, elaborate and describe the steps taken to address the problems identified: ____

LEASING AND PERMITTING

Is the resource Federally owned?: ______________________

If yes, competitive or non-competitive lease?: ______________________

Federal Leasing Chronology	Date
"Notice of Intent" to Obtain Lease	______
First Approval Received	______
_____ Unconditional	
_____ Conditions: ______________________	
Lease Signed	______
Plan of Operations Submitted	______
Plan of Operations Approved	______
Changes required in Plan of Operations: ______	
Drilling Plan Submitted	______
Drilling Plan Approved	______
Changes required in Drilling Plan: ______	

Explain delays in project schedule caused by slow-down in leasing process:

____

Total acres leased: ______________________

Environmental Report

When was environmental report prepared? Start: ______________
Completion: ______________

Environmental report prepared by whom?: ______________
Reviewed by whom?: ______________
When was review completed?: ______________
Changes required in project: ______________

Other Local, State, and Federal Permits Required

Permit	Agency	Date Request Submitted	Date Approved	Unusual Problems or Good Points

Effects, if any, of the following legislation on project approval process:

- The National Environmental Policy Act: ______
- The Clean Air Act of 1970: ______
- The Clean Air Act Amendments of 1977: ______
- The Federal Water Pollution Control Act: ______
- Solid Waste Disposal Act: ______
- Safe Drinking Water Act: ______
- Noise Control Act: ______
- Marine Protection and Sanctuaries Act: ______
- Resource Conservation & Recovery Act: ______
- Federal Land Policy and Management Act of 1977: ______
- Endangered Species Act (1973): ______

- Arts and Artifacts Indemnity Act: ______

- Toxic Substances Control Act: ______

- Endangered American Wilderness Act of 1978: ______

- The Non-Game Fish and Wildlife Bill: ______

- The Historic Preservation Act: ______

- Occupational Safety and Health Act of 1970 (OSHA): ______

- Forest and Rangeland Renewable Resources Act of 1974: ______

- National Forest Management Act of 1976: ______

Pertinent state or local legislation (list separately):

To what extent did the following groups affect the permitting/leasing process?:

Federal Agencies: ______________________________

State Government: ______________________________

Local Government: ______________________________

Local Community: ______________________________

Others (list): ______________________________

RESOURCE ASSESSMENT SUMMARY

	Original Estimate	Latest Estimate	Actual
Estimate Date			
Temperature Range			
Temperature: Best Estimate			
Measurement Technique			
Temperature Gradient			
Flow Rate			
Drilling Depth			
Reservoir Life Span			
Reservoir Pressure			
Wellhead Pressure			
Fluid Quality:			
TDS (ppm)			
Other			

Unique Resource Characteristics

Assessment Performer

Time to Complete Assessment

Assessment Technique

Describe problems encountered in assessment

Lithology

Productive Zone: ____________________

Reinjection Zone: ____________________

Describe any surprises encountered: ____________________

PLANNING

Site

Who made the site choice?: ______

How?: ______

Is it a "representative" site for this type application?: ______

Why or why not?: ______

Has the particular site generated any anticipated or unanticipated problems?: ______

If there were changes in site plans, describe (with dates): ______

Application

Who made the application choice?: ______________________________

How?: ______________________________

Is it a "representative" use in the relevant industry?: ______________

Why or why not?: ______________________________

Has the particular application caused any problems?

____

If there were changes in the application, describe (with dates): ________

Scale

Who made the scale choice?: ______

How?: ______

Is it a commercial scale for this type application?: ______

Why or why not?: ______

If not, what are additional scale-up problems?: ______

Has the particular scale caused any anticipated or unanticipated problems?: ______

If there were any changes in scale, describe (with dates): ______

Equipment/Technology

Who made the equipment choice?: ____

On what basis?: ____

Was the equipment specially developed for this application?: ____

If special, could it become a routinely produced system? Has the equipment caused any anticipated or unanticipated problems? If there were equipment changes, describe (with dates):

Project Planning Process

What parties played important roles in project planning decisions?:

	Application Selection	Site Selection	Equipment Selection	Scale Selection	Operations	Other (specify)
User(s)						
Operator						
Contractors*						
Local Government						
Other Local*						
State Government.*						
Federal Government.*						
Federal Contractor.*						

* Specify.

WELLS

(Complete one sheet for each well.)

Well Name: ______________________________

	Original Estimate	Latest Estimate	Actual
Date of Estimate			
Depth			
Bottomhole Temperature			
Wellhead Temperature			
Temperature Gradient			
Flow Rates:			
Hourly Peak			
Annual Average			
Summer Average			
Winter Average			
Production Peak Season Average			
Bottomhole Static Pressure			
Percent of Well Depth Hard Rock			

Drilling Technique ______________________________

____

Casing Material ______________________________

____

____

	Original Estimate	Latest Estimate	Actual
Downhole/Reinjection Pumps:			
Number			
Size (Hp)			
Expected Useful Life of Well			
Start of Drilling (date)			
Completion Date			

Well completion method: ______________________________

Special Features: ______________________________

Expected Useful Life of Well: ______________________________

Describe problems encountered and how handled. Include reasons for delays and cost overruns.

____

TRANSMISSION PIPELINES

(Attach any maps showing pipeline layout. Complete one sheet for each main line.)

Name of Pipeline: ______________________________

	Original Estimate	Latest Estimate	Actual
Date of Estimate			
Pipeline Length			
Pipe Diameter			
Kind of Insulation			
Insulation Thickness			
Trench Depth			
Geothermal Fluid or Other Fluid			
Inlet Temperature			
Outlet Temperature			
Inlet Pressure			
Outlet Pressure			
Heat Loss in Piping System			
Flow Rate			
Number of Pumps			
Size of Pumps			
Piping Material			
Casing Material			

Special Features ______________________________

____

____

Construction Start-Up
Construction Completion Date
Expected Useful Life

Describe problems encountered and how handled. Include reasons for delays and cost-overruns:

HEAT EXTRACTION AND DISTRIBUTION (attach any diagrams)

Process description: ______________________________

	Original Estimate	Latest Estimate	Actual
Kind of Heat Exchangers (floating head, reboiler, plate & frame, etc.)			
Number of Heat Exchangers			
Location of Heat Exchangers (well site or use site)			
For Each Heat Exchanger:			
Inlet Temperature of Geothermal Fluid			
Outlet Temperature of Geothermal Fluid			
Inlet Temperature of Secondary Fluid			
Outlet Temperature of Secondary Fluid			
Are Geothermal Fluids Cascaded from One Use to Another?			
If yes, list inlet and outlet temperatures for each process: ______________			
Overall Heat Transfer Coefficient (Btu/hr ft^2°F)			
Construction/Installation: Start-Up			
Completion			
Expected Useful Life of Equipment			

Describe problems encountered and how handled. Include reasons for delays and cost overruns:

Process Modifications/Retrofitting

Describe existing heating/cooling or industrial process system:

Describe required modifications to existing system:

Estimated Equipment Life:

For Space and Water Heating/Cooling Systems:

Number of Heating Days Per Year: ____________________
Number of Cooling Days Per Year: ____________________

Building Density: ____________________

For Industrial Processes:

Temperature requirements for each process: ____________________

Total heat requirement for each process: ____________________

DISPOSAL

Type of Disposal System:
____ Deep-Well Reinjection
____ Evaporation Pond
____ Direct Discharge into Surface Waters
____ Other

Describe disposal system: ____________________

Problems encountered: ______________________________

Equipment Life: ______________________________

ENVIRONMENTAL SAFEGUARDS

Discuss environmental impact of this geothermal project. Include particular environmental problems encountered and how handled:

Extraction: ______________________________

Distribution/Utilization: ______________________________

Disposal: ______________________________

Give description of each major piece of pollution control equipment:

Describe environmental monitoring:

PROJECT COST INFORMATION
(Attach additional sheets if project costs extend beyond 1982)

Cost Category	Year 1978	1979	1980	1981	1982
o Resource Acquisition and Related Costs:					
-- Lease Bonus Bid					
-- Purchase Price of Land					
-- Permitting					
-- Geological & Geophysical Exploration					
-- Environmental Assessment					
-- Other					
o Well Drilling:					
-- Design and Planning for Well					
-- Tangible Well Equipment					
-- Intangible Drilling Costs (includes site preparation and well testing)					
o Distribution System and Retrofit:					
-- Design/Planning/Bidding					
-- Pump Houses and Other Structures					
-- Geothermal Space Heating System in New Buildings					
-- Equipment Not Used Exclusively with Geothermal Energy					
-- Disposal Equipment					
-- All Other Construction Costs					
o General and Administrative Expenses					
o Direct DOE-Related Costs (e.g., conferences, publicity)					

	Original Estimate	Latest Estimate	Actual
Anticipated Yearly O&M Costs			
Yearly Rental/Royalty Payment			
Unit Selling Price (if applicable)			
Total Capital Cost			
Federal Share			
%			
$			
Federal Share Applicable to Which Project Phases?			
Non-Federal Share:			
Amount			
% Debt			
Interest Rate on Debt			

Expenditures To Date: $ ____________ Date: ____________

Reasons for cost overruns: ____________

Non-Federal Sources of Funding: ____________

Describe problems encountered in arranging financing: ____________

Contractual arrangements with constructor (cost plus, fixed fee, etc.): ____________

First-of-a-kind project costs (describe and list costs for extra instrumentation, frequent down-time for examining the system, etc.): ____________

Describe customer billing system: ____________________

Depreciation methods used for financial reporting: ____________________

Depreciation methods used for tax purposes: ____________________

PROJECT MANAGEMENT

Project organizational structure: ______________________________

Who was responsible for day-to-day operations during project planning and construction?: ______________________________

Who will be responsible for operations and maintenance once project enters operational phase?: ______________________________

Describe any significant Federal involvement in project management:

____

OPERATIONS

Monthly Energy Production Data:

Month	Btu's Delivered	Average Flow Rate	Peak Flow Rate	Temperature

Describe incidents of extended down-time:

Describe testing/monitoring procedures and equipment. Was testing planned as a regular part of project's operation and/or added later?:

PROJECT RESULTS/ACHIEVEMENTS

To what extent does the project serve its originally established goals?:

Pre-project status of and operational experience with technology employed by the project:

Status of technology after construction and operation: ____________________

What is the attitude of users (generally positive, generally negative, mixed)? Explain: ____________________

What means are being employed to disseminate information on project results?: ____________________

Has there been any movement to expand the system at its site (expressed interest, decision to expand, expansion underway, expansion completed)? Explain: ____________________

Have others expressed an interest in using a similar system elsewhere? (Include how interest expressed, list of other projects underway, etc.)

Estimated potential market in the project's area for the type of energy provided:

Percent of potential market served:

Likely constraints on expansion: